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**MARINE MAMMAL DEMOGRAPHICS OF THE OUTER
WASHINGTON COAST DURING 2008 - 2009**

by

Ana Širović, Erin M. Oleson, John Calambokidis,
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14. ABSTRACT In 2007 it was proposed that the U.S. Navy's Quinalt Underwater Tracking Range (QUTR) off the outer Washington coast be expanded into deep water habitats (used by beaked and sperm whales) and along the coastal shelf (where coastal cetaceans forage). In 2004 an acoustic and visual monitoring effort was initiated within the boundaries of the expanded QUTR to characterize the vocalizations of marine mammal species present in the area, to determine the year-round seasonal presence of all odontocete and mysticete whales, and to evaluate the distribution of cetaceans near the Navy range. Acoustic data have been collected at two sites using autonomous High-frequency Acoustic Recording Packages (HARPs). This report summarizes acoustic data collected from June 2008 to June 2009. Seasonal occurrence and relative abundance of species consistently identified in the acoustic data are discussed in the context of earlier visual and acoustic data collections.					
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Contents

LIST OF TABLES	ii
LIST OF FIGURES	iii
PROJECT BACKGROUND	1
METHODS	2
<i>DATA COLLECTED TO DATE</i>	2
<i>ACOUSTIC DATA ANALYSIS</i>	2
RESULTS	3
<i>ACOUSTIC MONITORING</i>	3
FINDINGS BY SPECIES	3
<i>BLUE WHALES</i>	3
<i>FIN WHALES</i>	5
<i>HUMPBACK WHALES</i>	7
<i>GRAY WHALES</i>	8
<i>BEAKED WHALES</i>	10
<i>SPERM WHALES</i>	10
<i>KILLER WHALES</i>	11
<i>PACIFIC WHITE-SIDED DOLPHINS</i>	12
<i>RISSO'S DOLPHINS</i>	14
<i>UNIDENTIFIED ODONTOCETES</i>	14
<i>PORPOISES</i>	16
<i>PINNIPEDS</i>	17
ANTHROPOGENIC NOISE SOURCES	17
<i>MID-FREQUENCY ACTIVE (MFA) SONAR</i>	17
<i>EXPLOSIONS</i>	18
<i>SHIPPING</i>	21
REFERENCES	22
INITIAL DISTRIBUTION LIST	24

List of Tables

Table 1:	Acoustic data collection near QUTR since July 2004.	2
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List of Figures

Figure 1:	Locations of two High-frequency Acoustic Recording Packages, S1 and S2, and the monthly visual survey track (solid line) from Westport harbor.	1
Figure 2:	Long term spectral average [LTSA] (above) and spectrogram (below) of blue whale A and B calls (shown in sequence) recorded at the inshore site in September 2008.	4
Figure 3:	LTSA (above) with a red box marking the period of blue whale D calls enlarged in the spectrogram (below).	4
Figure 4:	Occurrence of blue whale A, B and D calls between June 2008 and June 2009 recorded at the inshore site.	5
Figure 5:	LTSA (above) and spectrogram (below) of fin whale 20 Hz calls recorded at the inshore site in October 2008.	6
Figure 6:	Occurrence of fin whale calls between June 2008 and June 2009 recorded at the inshore site.	6
Figure 7:	LTSA (above) and spectrogram (below) of humpback whale song recorded at the inshore site in October 2008.	7
Figure 8:	Occurrence of humpback whale sounds (song and non-song) between June 2008 and June 2009 recorded at the inshore site.	8
Figure 9:	Occurrence of humpback whale song only between June 2008 and June 2009 recorded at the inshore site.	8
Figure 10:	Spectrogram of gray whale M3 call type recorded at the inshore site in October 2008.	9
Figure 11:	Occurrence of gray whale M3 call type between June 2008 and June 2009 recorded at the inshore site.	10
Figure 12:	Occurrence of sperm whale clicks between June 2008 and June 2009 recorded at the inshore site.	11
Figure 13:	Occurrence of sperm whale clicks between June 2008 and June 2009 by hour of the day.	11

Figure 14:	Occurrence of killer whale ecotypes between June 2008 and June 2009 recorded at the inshore site.	12
Figure 15:	LTSA of Pacific white-sided dolphin echolocation clicks recorded at the inshore site in August 2008.	13
Figure 16:	Occurrence of Pacific white-sided dolphin echolocation clicks between June 2008 and June 2009 recorded at the inshore site.	14
Figure 17:	Occurrence of whistles, burst-pulses, and echolocation clicks from unidentified odontocetes between June 2008 and June 2009 recorded at the inshore monitoring site.	15
Figure 18:	Occurrence of clicks, whistles, and burst-pulse sounds from unidentified odontocetes between June 2008 and June 2009 by hour of the day.	15
Figure 19:	LTSA of high frequency narrow bandwidth pulses (outlined by red box), likely aliased porpoise pulses, recorded at the inshore site in October 2008.	16
Figure 20:	Occurrence of high-frequency narrow-bandwidth (NBHF) clicks, thought to be produced by a porpoise, recorded between June 2008 and June 2009.	17
Figure 21:	LTSA (above) and spectrogram (below) of mid-frequency active (MFA) sonar recorded at the inshore site on 15 May 2009.	18
Figure 22:	LTSA of several explosions recorded in August 2008 (above), with spectrogram (middle) and time series (below) of one event.	19
Figure 23:	Occurrence of explosions between June 2008 and June 2009.	20
Figure 24:	Occurrence of explosions between June 2008 and June 2009 by hour of the day.	20
Figure 25:	Occurrence of boat and ship noise between June 2008 and June 2009.	21

Marine Mammal Demographics of the Outer Washington Coast during 2008 - 2009

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Project Background

The outer Washington coast of the United States is a productive marine ecosystem home to many species of marine mammals, including beaked whales, killer whales, and other cetaceans and pinnipeds. The Navy's Quinault Underwater Tracking Range (QUTR), part of the Northwest Training Range Complex, is located along the outer Washington coast and has been proposed for expansion (Federal Register, **Vol. 74**:41712, 31 July 2007) into deep water habitats, used by beaked and sperm whales, and south along the shelf, where coastal cetaceans forage.

In July 2004, an acoustic and visual monitoring effort was initiated within the boundaries of the expanded QUTR to characterize the vocalizations of marine mammal species present in the area, to determine the year-round seasonal presence of all odontocete and mysticete whales, and to evaluate the distribution of cetaceans near the Navy range. Two High-frequency Acoustic Recording Packages (HARPs) have been deployed near the QUTR, one in deep water (approximately 650 m) within Quinault Canyon (Figure 1: S1) and a second in inshore waters (~100 m) on the shelf (Figure 1: S2). In addition, visual surveys have been conducted on about a monthly basis in the region (Figure 1).

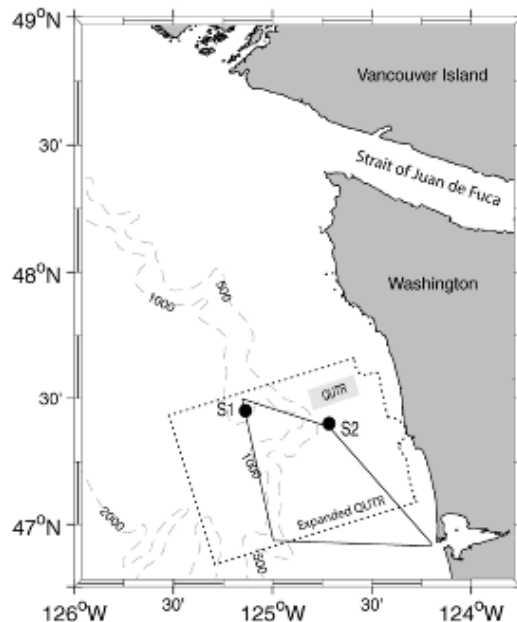


Figure 1. Locations of two High-frequency Acoustic Recording Packages, S1 and S2, and the monthly visual survey track (solid line) from Westport harbor. Only data from S2 were recovered during the period covered by this report.

Methods

Data Collected to Date

Acoustic data were collected at two sites using autonomous High-frequency Acoustic Recording Packages (HARPs) sampling at 200 kHz with 1/7 duty cycle in the 2008/09 sampling season (Table 1). A glitch in the data logging system resulted in an abandonment of the duty cycle on 1 January 2009 and produced continuous recordings for five days, after which the duty cycle resumed. The HARP deployed offshore during this period was lost. Thus data are available only for the inshore site, S2, between June 2008 and June 2009. Likewise, the HARP deployed inshore from December 2009 to January 2011 was lost, presumably due to the intense bottom trawling that occurs in this area. We continued acoustic data collection at the offshore site in January 2011 and at the inshore site in May 2011.

Table 1. Acoustic data collection near QUTR since July 2004. Period of instrument deployment analyzed in this report is shown in bold, and ongoing data collection is in italics. Results of acoustic monitoring through June 2008 were described by Oleson *et al.* (2009).

Acoustic Monitoring Period	Sample Rate & Duty Cycle (on/off, min.)	S1: Offshore	S2: Inshore
OCNMS01: July – October 2004	80 kHz continuous	Yes	Lost
OCNMS02: October 2004 – July 2005	80 kHz 10/20	Data ended 1/05	
OCNMS03: July 2005 – August 2006	80 kHz 6/12	Data ended 2/06	
OCNMS04: August 2006 – March 2007	80 kHz 6/12	Data ended 2/07	Yes
OCNMS05: April – July 2007	80 kHz continuous	Yes	Yes
OCNMS06: July 2007 – June 2008	200 kHz 5/35	Yes	
OCNMS07: October 2007 – June 2008	200 kHz 5/30		Yes
OCNMS08: June 2008 – June 2009	200 kHz 5/35	Lost	Yes
OCNMS09: December 2009 – January 2011	200 kHz 5/30		Lost
<i>OCNMS10: January 2011 –</i>	<i>200 kHz continuous</i>	<i>Ongoing</i>	
<i>OCNMS10: May 2011 –</i>	<i>200 kHz continuous</i>		<i>Ongoing</i>

Acoustic Data Analysis

The daily presence of acoustic signals from multiple marine mammal species including blue whales (*Balaenoptera musculus*), fin whales (*B. physalus*), gray whales (*Eschrichtius robustus*), humpback whales (*Megaptera novaeangliae*), sperm whales (*Physeter macrocephalus*), killer whales (*Orcinus orca*), Risso's dolphins (*Grampus griseus*), and Pacific white-sided dolphins (*Lagenorhynchus obliquidens*) was analyzed.

Killer whale sounds were identified to ecotype by Amalis Riera (University of Victoria) and John K. B. Ford (University of British Columbia). Pinniped and likely porpoise sounds were also identified in the data, as was the daily presence of anthropogenic noise, such as explosions and shipping. There was also a single detection of Navy sonar in one day during this report period. All data were analyzed by visually scrutinizing long term spectral averages (LTSAs) in appropriate frequency bands. When a sound of interest was identified in the LTSA, examining the waveform or spectrogram at the time of interest was possible to identify particular sounds to species or source, as necessary. Acoustic classification was carried out either from comparison to species-specific spectral characteristics or through analysis of the time and frequency characters of individual sounds.

For efficient analysis, data were divided into three frequency bands and each band was analyzed for the sounds of an appropriate subset of species or sources. Blue, fin, and gray whale sounds were classified under low-frequency (below 1 kHz), humpback and sperm whales, pinnipeds, shipping, explosions, and sonar were classified under mid-frequency (up to 5 kHz), while the remaining odontocete sounds were considered high-frequency (above 10 kHz). For the analysis of the mid-frequency recordings, data were decimated by a factor of 20, while for the low-frequency analysis, they were decimated by a factor of 100. The LTSAs were created using a 5 s time average with 100 Hz resolution for high-frequency, 10 Hz resolution for mid-frequency, and 1 Hz resolution for low-frequency data analysis.

In this report, we summarize acoustic data collected from June 2008 until June 2009 since the last comprehensive report (Oleson *et al.* 2009). We discuss seasonal occurrence and relative abundance of species which can be consistently identified in the acoustic data in the context of earlier visual and acoustic data collections, as well as the visual observations conducted during the same period as reported by Oleson *et al.* (2010).

Results

Acoustic Monitoring

Cetacean species detected in the acoustic data set between June 2008 and June 2009 at the S2 site include: blue whales, fin whales, gray whales, humpback whales, sperm whales, killer whales, and Pacific white-sided dolphins. Also, a number of sounds that were detected have not yet been classified to species, but they include likely porpoise clicks, a variety of dolphin signals, and pinniped calls. Details of species-specific trends in acoustic activity are described below.

Findings by Species

Blue Whales

Three different calls were used to identify the presence of blue whales in the dataset. Calls of type A and B (Figure 2) are representative of the blue whale population found in the eastern North Pacific (McDonald *et al.* 2006). They are produced by males only, and therefore likely associated with pre-mating and mating behavior (Oleson *et al.* 2007). D calls (Figure 3) are similar worldwide and are associated with feeding animals (Oleson *et al.* 2007).

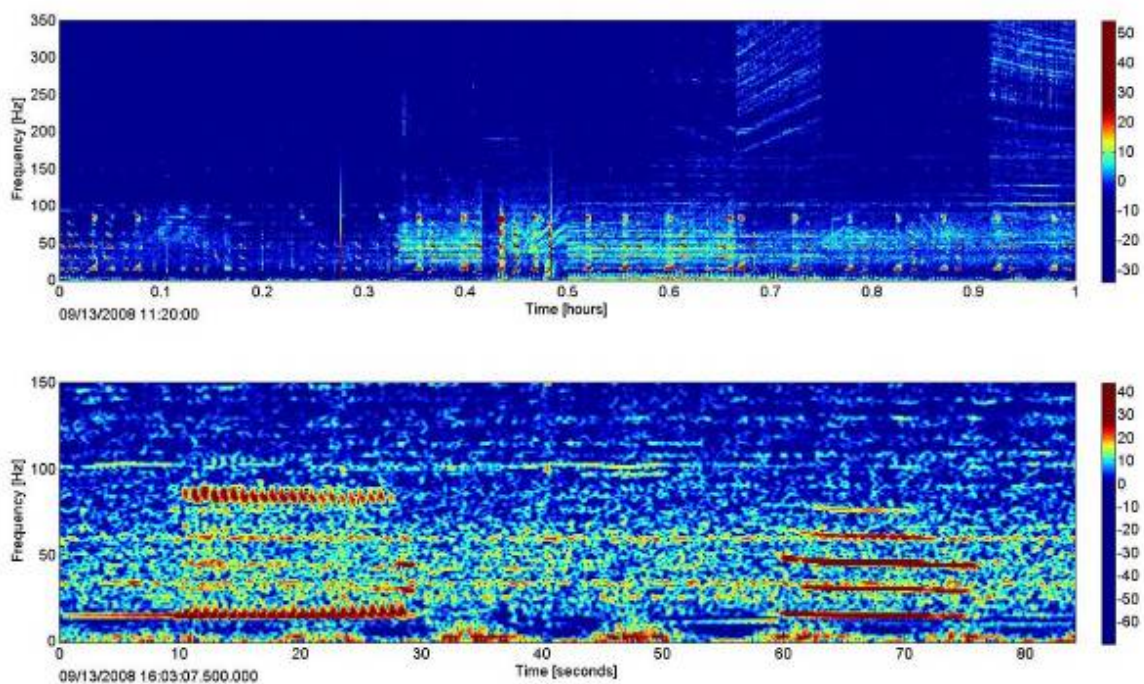


Figure 2. Long term spectral average [LTSA] (**above**) and spectrogram (**below**) of blue whale A and B calls (shown in sequence) recorded at the inshore site in September 2008. (Spectrogram made with 1500-point FFT and 90% overlap.)

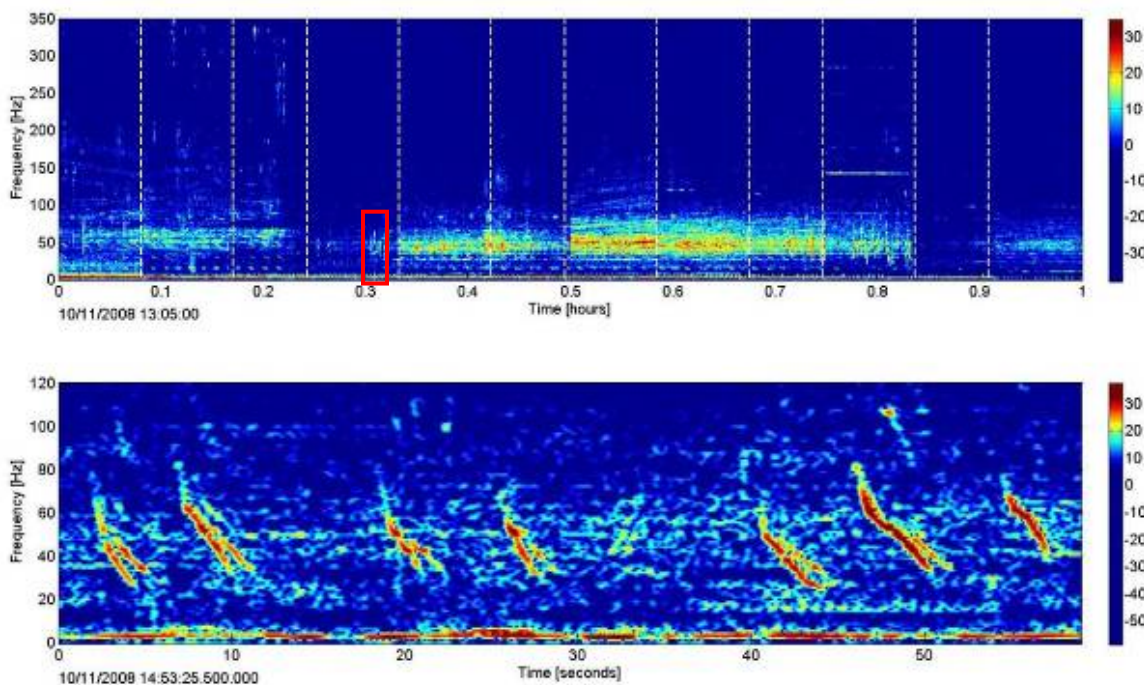


Figure 3. LTSA (**above**) with a red box marking the period of blue whale D calls enlarged in the spectrogram (**below**). Recorded at the inshore site in October 2008. (Spectrogram made with 1500-point FFT and 90% overlap.)

Blue whale calls were detected at the inshore site between August 2008 and February 2009, with peak calling from October to December (Figure 4). This seasonal presence is consistent with seasonal occurrence of blue whale calls off Washington as reported by Watkins *et al.* (2000) and Burtenshaw *et al.* (2004). Blue whales are not frequently sighted at this location (Calambokidis *et al.* 2004), but the first sighting in decades was reported by visual surveys associated with this project during this monitoring period (Oleson *et al.* 2010). This visual sighting occurred in January, which is consistent with the acoustic detections in late fall and winter.

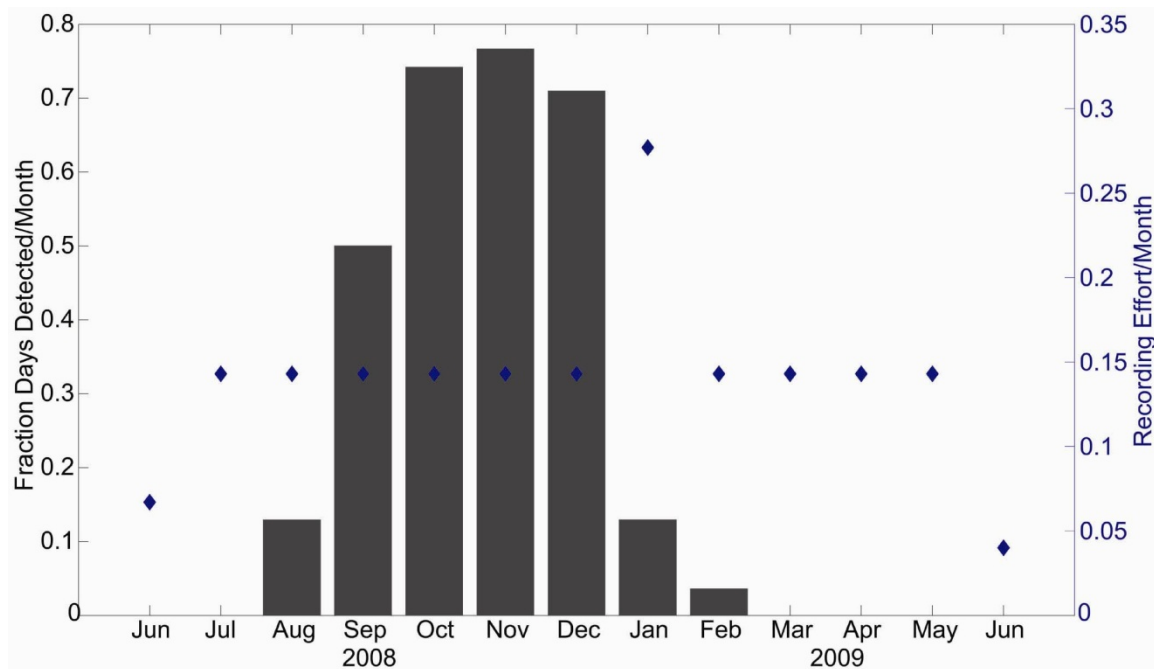


Figure 4. Occurrence of blue whale A, B and D calls between June 2008 and June 2009 recorded at the inshore site. Black bars represent the fraction of days blue whales were detected in a month and blue diamonds represent monthly recording effort. Recording effort of approximately 0.15 months is indicative of 1/7 duty cycle. More effort in January reflects the abandonment of the duty cycle and transition to continuous recording for 5 days. Less effort in June 2008 and June 2009 indicates that the instrument was deployed and recovered during these months, resulting in less effort.

Fin Whales

The occurrence of 20 Hz pulses (Figure 5) was used as an indication of fin whale presence in this dataset. Fin whale calls were most commonly detected between September and April (Figure 6). They were among the most commonly recorded calls and were detected on more than 90% of days during four months (October, December, January, and February), but they were absent from the data during May and June (Figure 6). These findings are also consistent with earlier acoustic surveys for fin whales conducted farther offshore (Watkins *et al.* 2000) and the sightings of fin whales made during the visual surveys in January 2009.

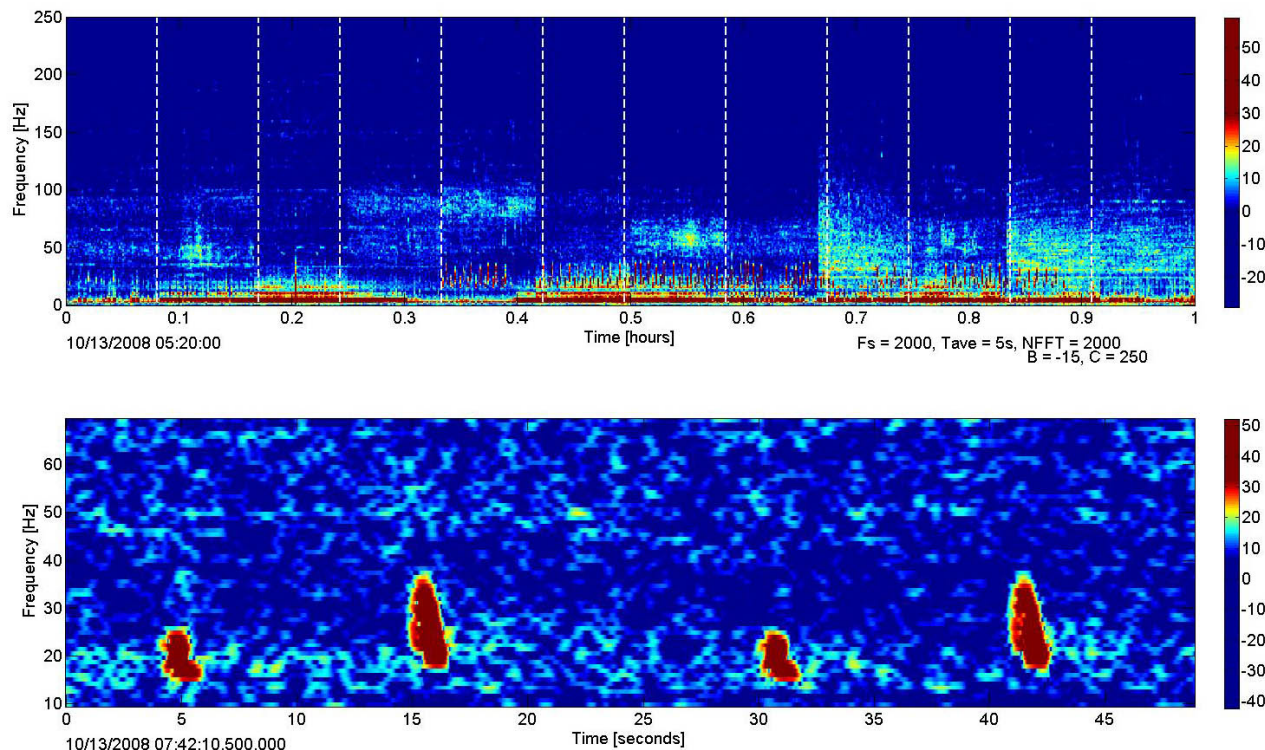


Figure 5. LTSA (above) and spectrogram (below) of fin whale 20 Hz calls recorded at the inshore site in October 2008. (Spectrogram made with 3000-point FFT and 98% overlap.)

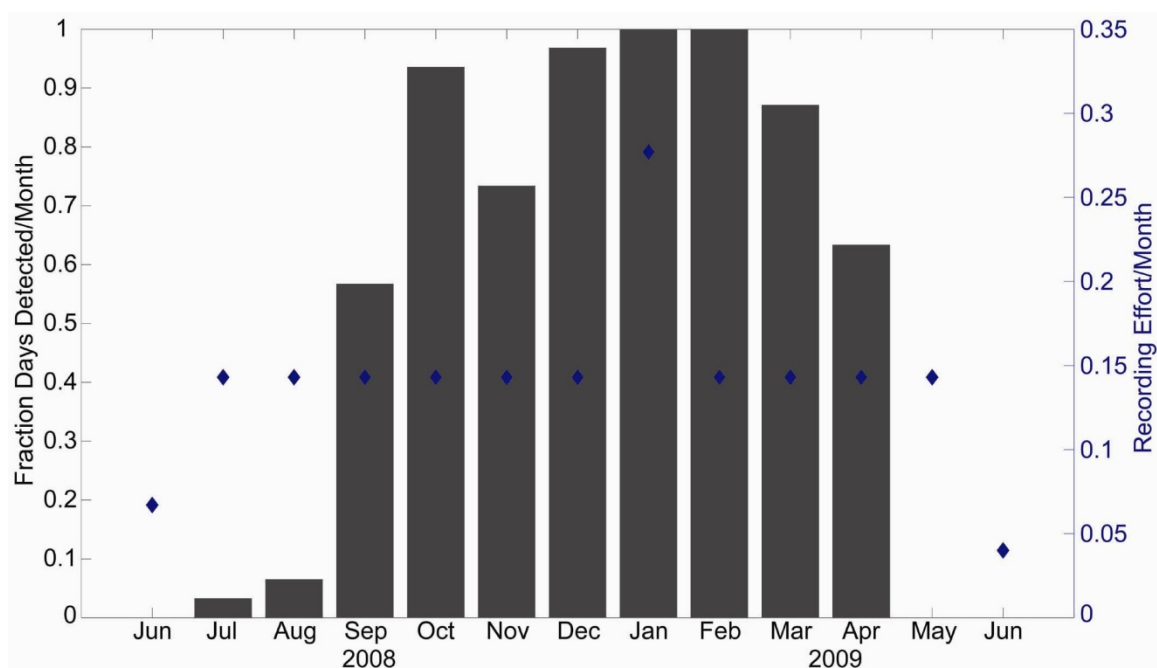


Figure 6. Occurrence of fin whale calls between June 2008 and June 2009 recorded at the inshore site. Black bars represent the fraction of days fin whales were detected in a month and blue diamonds represent monthly recording effort.

Humpback Whales

Energy in most humpback whale calls is centered between 100 and 3,000 Hz. Humpback whale song (Figure 7) is categorized by the repetition of units, phrases and themes (Payne and McVay, 1971). Non-song vocalizations, such as social sounds and feeding sounds, consist of short duration (0.15 to 2.5 seconds long) individual units (Dunlop *et al.* 2007, Stimpert *et al.* 2011). Presence of both song and non-song vocalizations was analyzed in the acoustic data.

Consistent with previous recordings at this site, humpback whales were most commonly detected in the acoustic recordings between September and December (Figure 8), which was also the peak time for humpback singing (Figure 9). The lower level of calling from February through May is also consistent with previous years' findings (Oleson *et al.* 2009). Our record continues to show over-wintering presence of humpback whales in higher latitudes (Shelden *et al.* 2000). Visual and acoustic detections of humpback whales in this area do not fully overlap, as most visual sightings occur during the summer and early fall (Oleson *et al.* 2010), which is likely the result of the strong seasonal variation in humpback whale singing and other vocal behavior throughout their range.

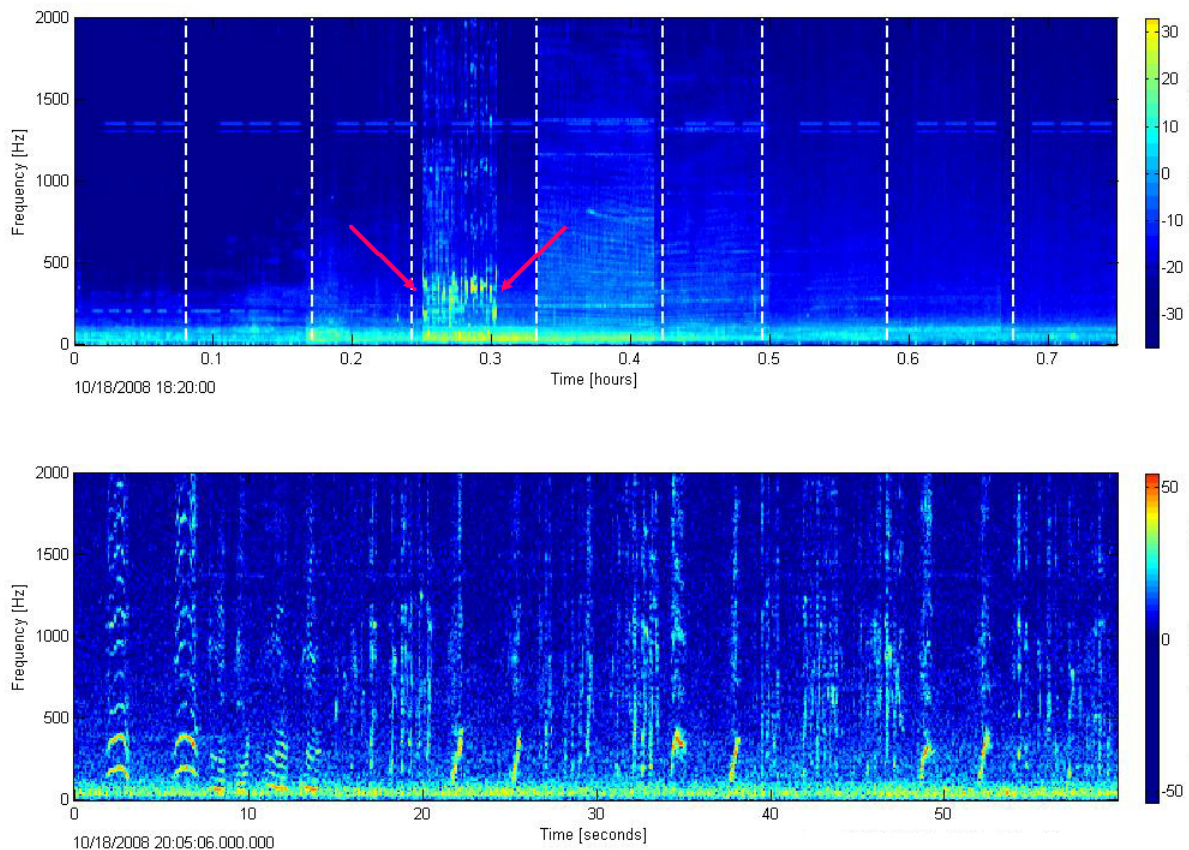


Figure 7. LTSA (**above**) and spectrogram (**below**) of humpback whale song recorded at the inshore site in October 2008. White broken lines on the LTSAs denote start and end of each duty cycle and red arrows point to the section of data containing humpback song as shown in the spectrogram. Note that in this example, the song was recorded only during a single duty cycle.

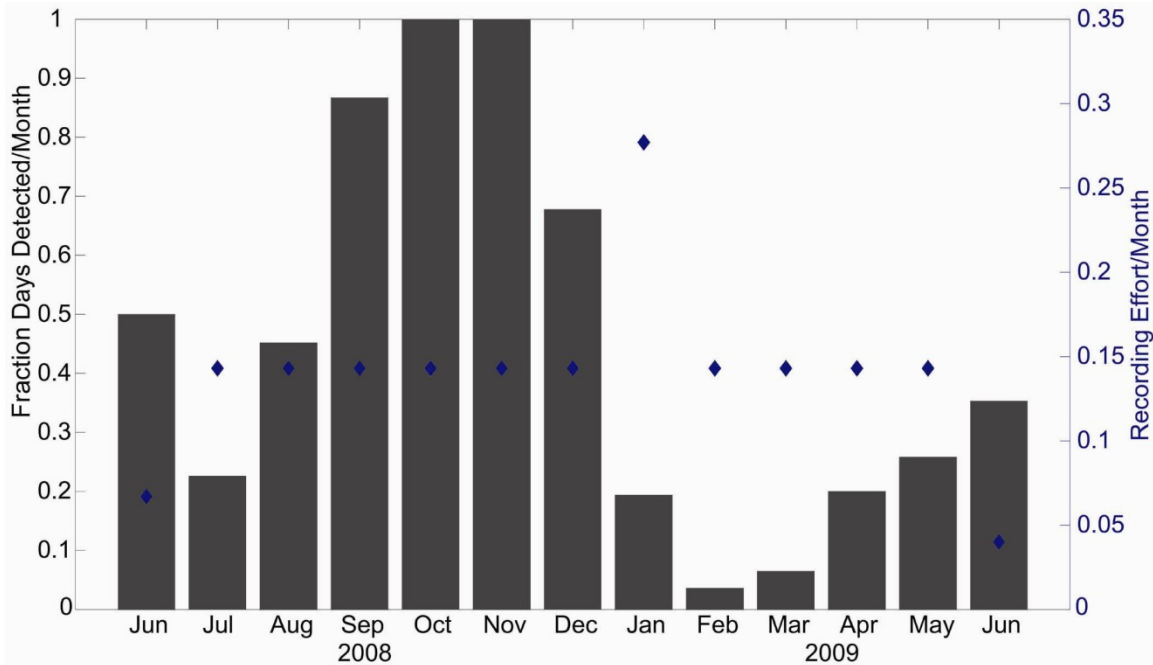


Figure 8. Occurrence of humpback whale sounds (song and non-song) between June 2008 and June 2009 recorded at the inshore site. Black bars represent the fraction of days humpback whales were detected in a month and blue diamonds represent monthly recording effort.

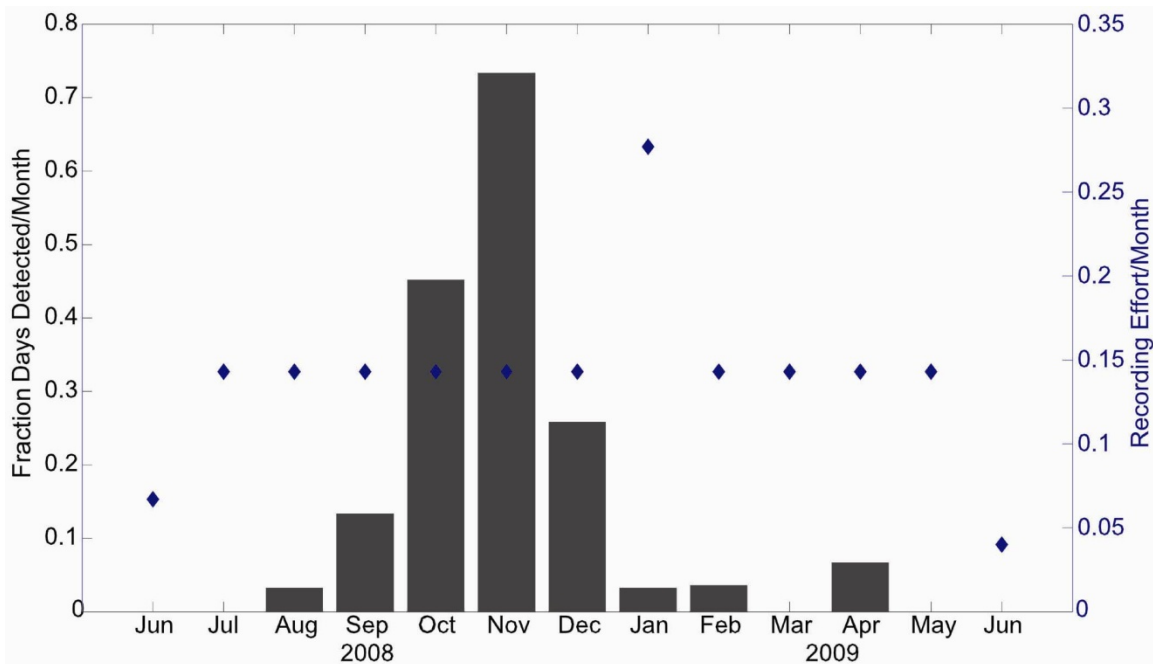


Figure 9. Occurrence of humpback whale song only between June 2008 and June 2009 recorded at the inshore site. Black bars represent the fraction of days humpback whales were detected in a month and blue diamonds represent monthly recording effort.

Gray Whales

While gray whale calls were often difficult to distinguish among humpback whale calls, the gray whale M3 call type, a short-duration, low-frequency moan (Figure 10; Crane and

Lashkari 1996), could be most reliably detected in the data and thus was used as a proxy for gray whale presence at site S2. Gray whale M3 calls were detected almost year round (Figure 11), but at variable numbers, which are likely indicative of different stocks or different life stages. The majority of calling occurred from December through February, which corresponds to the timing of the southbound gray whale migration from the feeding grounds in Bering and Chukchi Seas to the breeding grounds off Baja California, Mexico. While the whales generally follow a path farther offshore during this southbound migration, something apparent in the visual sighting positions, they could still be heard at the inshore site. Lower levels of calling until April could be reflecting the fact that gray whales are thought to be less vocal on the northbound migration, presumably trying to avoid detection by killer whales. Higher call rates in the summer likely represent the resident population that feeds in the northeast Pacific during this period. No large aggregations of feeding gray whales, however, were observed by the visual surveys during the summer since this was documented in 2007 (Oleson *et al.* 2010).

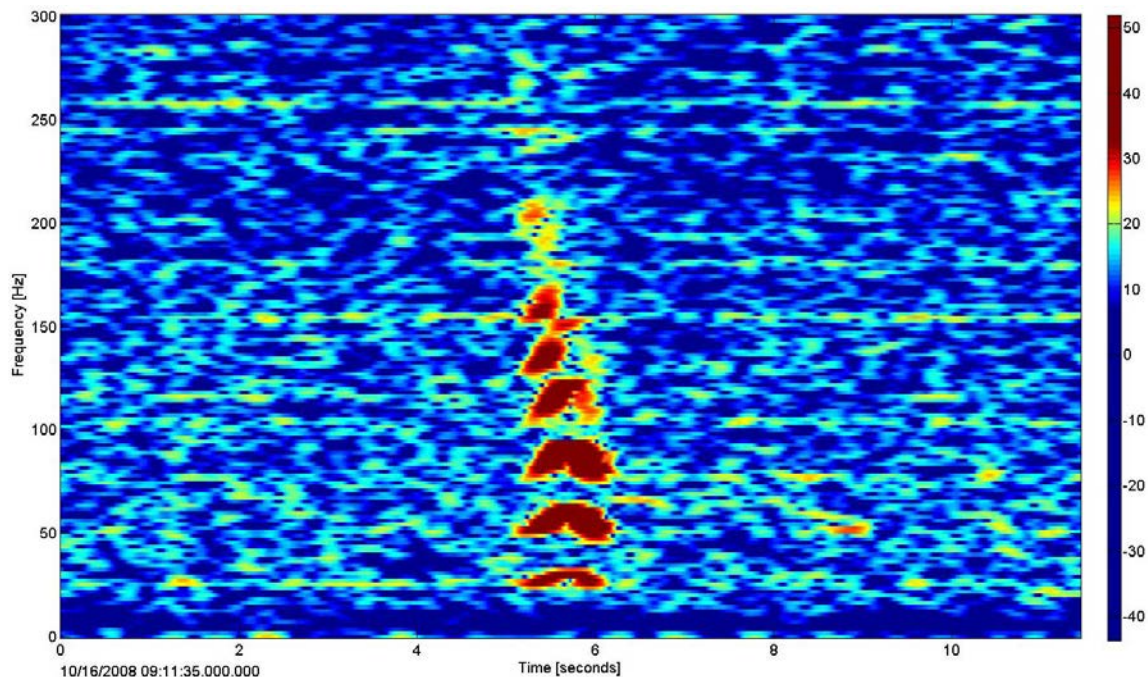


Figure 10. Spectrogram of gray whale M3 call type recorded at the inshore site in October 2008. (Spectrogram made with 1500-point FFT and 98% overlap.)

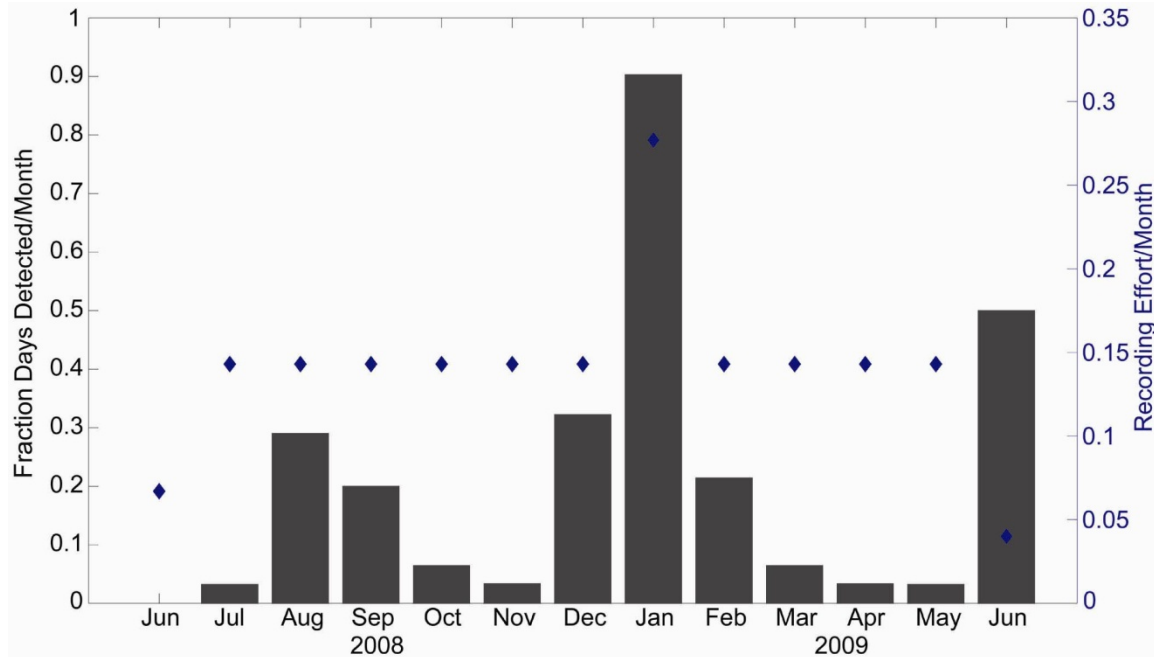


Figure 11. Occurrence of gray whale M3 call type between June 2008 and June 2009 recorded at the inshore site. Black bars represent the fraction of days gray whales were detected in a month and blue diamonds represent monthly recording effort.

Beaked Whales

No beaked whales were detected in this data set, which is not surprising considering that the location of the inshore recorder is shallower water than is known to be beaked whale habitat. Likewise, no beaked whales were sighted during visual surveys conducted from June 2008 until June 2009 (Oleson *et al.* 2010).

Sperm Whales

Sperm whale clicks generally contain energy that extends from 2-20kHz, with the majority of energy between 10-15 kHz and spectral peaks around 12 kHz (Møhl *et al.* 2003). Sperm whale clicks were detected through most of the year at the inshore monitoring site, although there was a notable absence of clicks between February and May 2009 (Figure 12). In previous years, sperm whales were detected at this location generally from April to November (Oleson *et al.* 2009). Their presence later in the year, and appearance in 2009 later than usual, could be an indicator of differing environmental conditions in 2008/09 in comparison to prior years of monitoring. As in previous years, there was a somewhat higher rate of click detections during nighttime at this location than during the day (Figure 13; Oleson *et al.* 2009). No sperm whales were seen during visual surveys conducted during this acoustic monitoring period (Oleson *et al.* 2010).

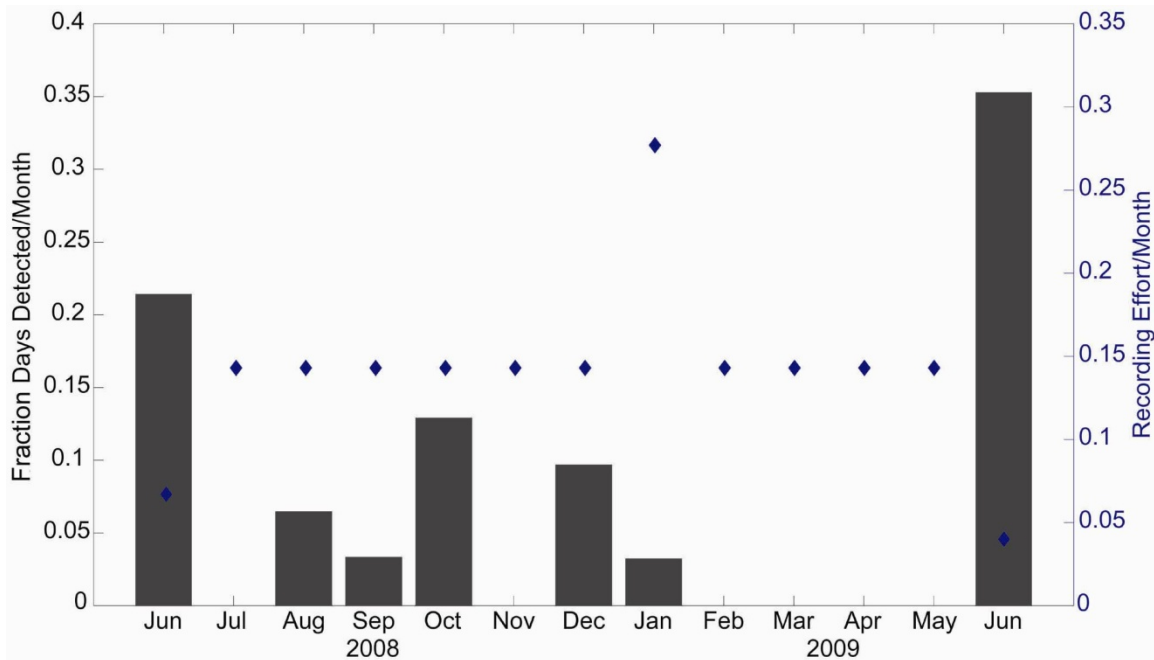


Figure 12. Occurrence of sperm whale clicks between June 2008 and June 2009 recorded at the inshore site. Black bars represent the fraction of days sperm whales were detected in a month and blue diamonds represent monthly recording effort.

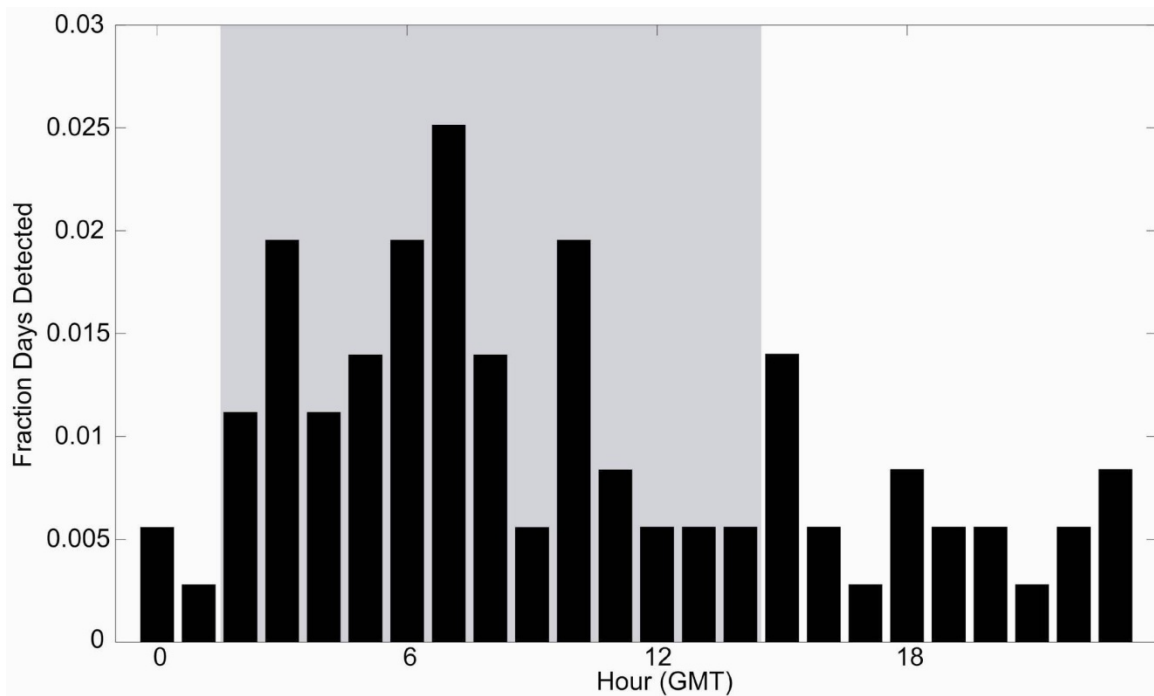


Figure 13. Occurrence of sperm whale clicks between June 2008 and June 2009 by hour of the day. Shaded grey area represents average night period at this location through the year.

Killer Whales

Three distinct killer whale ecotypes were detected acoustically, including Northern and Southern Residents and Transients (Figure 14). All Northern Resident killer whales

belonged to clan G, while Southern Residents were from clans K, J, and L. Both the California and British Columbia transient killer whale dialects were detected. There was no overlap in seasonal presence of the two different Resident ecotypes. Northern Resident killer whales were detected generally in the summer of 2008, while Southern Residents were detected during the late winter through early summer of 2009. Both Resident ecotypes were previously detected in this area during the same months of the year (Calambokidis *et al.* 2004, Oleson *et al.* 2009); so the temporal separation observed during this year may not be a persistent pattern. Transients, on the other hand, overlapped with both resident ecotypes, as they did in earlier years of surveys. No killer whales were sighted in visual surveys during this period (Oleson *et al.* 2010), but have been sighted numerous times earlier and in previous studies (Calambokidis *et al.* 2004, Oleson *et al.* 2009).

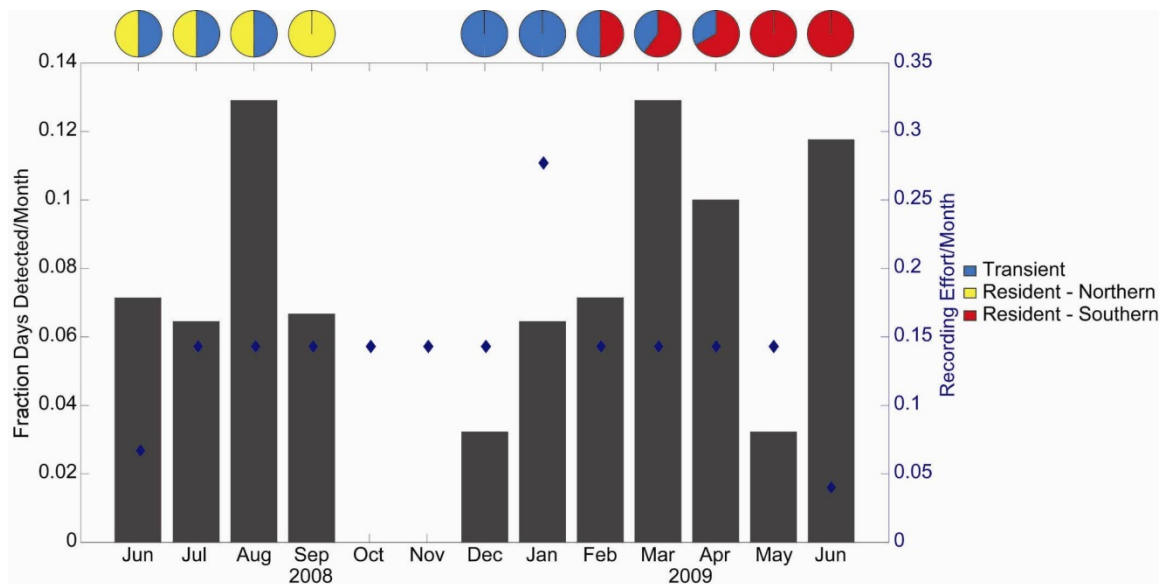


Figure 14. Occurrence of killer whale ecotypes between June 2008 and June 2009 recorded at the inshore site. Black bars represent the fraction of days killer whales were detected in a month and blue diamonds represent monthly recording effort. The pie charts above the panel indicate relative occurrence of each killer whale ecotype during each month. Killer whale ecotype identification courtesy of Amalis Riera (University of Victoria) and John K. B. Ford (University of British Columbia).

Pacific White-sided Dolphins

In contrast to findings from previous monitoring, there was a drastic decrease of Pacific white-sided dolphins in the acoustic data collected from June 2008 until June 2009. Pacific white-sided dolphin echolocation clicks are broadband impulses with the majority of energy between 20 and 60 kHz (Figure 15), and can be identified to species by their distinctive banding patterns observable in the LTSA with energy peaks at 22, 26.5-27, 37-39. These peaks are likely examples of local differences in their clicks, as values are slightly different from those recorded in the Southern California Bight (Soldevilla *et al.* 2010). Acoustic detections of Pacific white-sided dolphins during this study occurred during only a few days in five months between August and March (Figure 16). In previous years, Pacific white-sided dolphins were the most commonly detected

odontocete in the acoustic dataset and they were heard for nine to ten months each year, albeit more commonly offshore (Oleson *et al.* 2009). Only one group of Pacific white-sided dolphins was sighted during the visual surveys conducted over this time period, and they were farther offshore than our recorder (Oleson *et al.* 2010). This decrease in Pacific white-sided dolphins in the area from June 2008 until June 2009 could be an indication of a change in oceanographic conditions that may drive their spatial distribution. Further investigation of the variation in environmental conditions among different survey years would help shed a light on this difference in Pacific white-sided dolphin presence in the survey area.

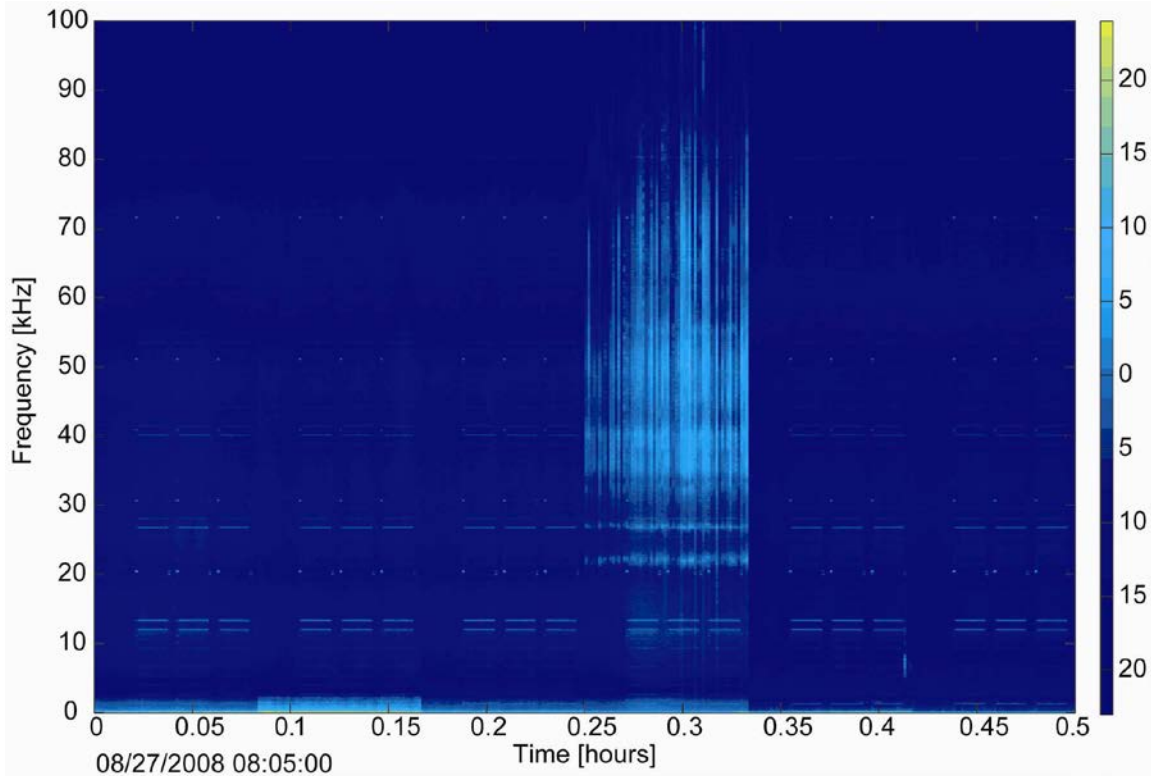


Figure 15. LTSA of Pacific white-sided dolphin echolocation clicks recorded at the inshore site in August 2008. Note the characteristic spectral banding.

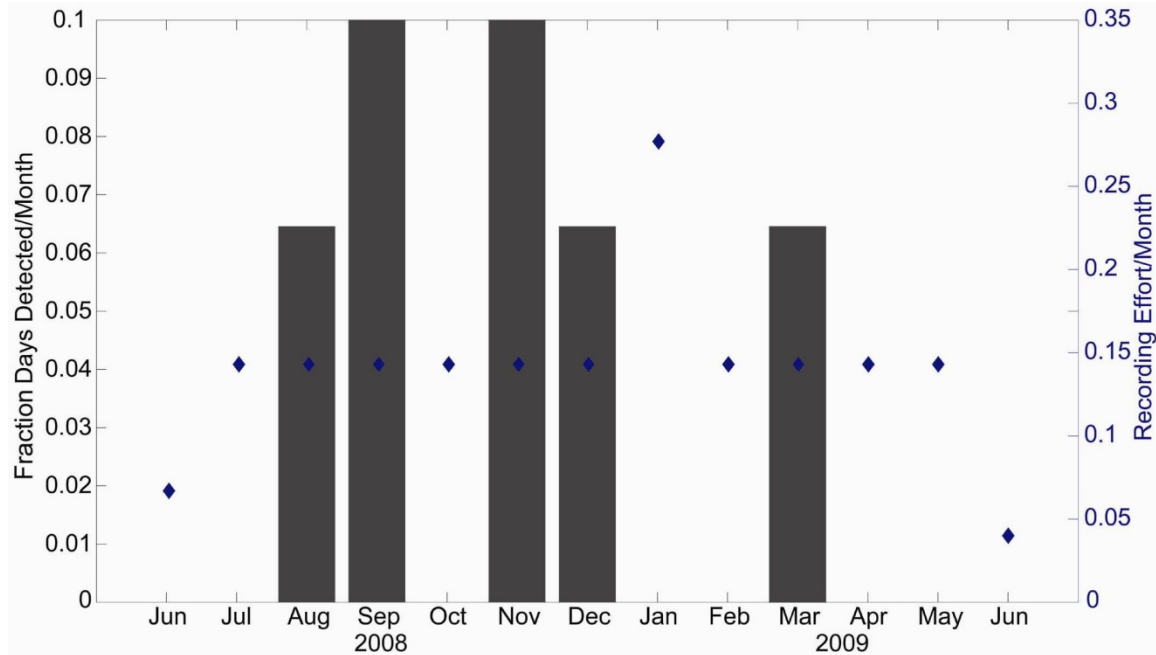


Figure 16. Occurrence of Pacific white-sided dolphin echolocation clicks between June 2008 and June 2009 recorded at the inshore site. Black bars represent the fraction of days Pacific white-sided dolphin clicks were detected in a month and blue diamonds represent monthly recording effort.

Risso's Dolphins

Risso's dolphins were not acoustically detected or visually observed between June 2008 and June 2009, and generally have been sighted infrequently during recent surveys (Oleson *et al.* 2009, 2010). They were, however, the most commonly sighted odontocete within the study area during aerial surveys in the late 1980s (Green *et al.* 1992).

Unidentified Odontocetes

A large number of whistles, burst-pulses, and echolocation clicks have been detected that currently cannot be identified to species. Delphinid species thought to occur here, but whose sounds repertoire is not fully described, include northern right whale dolphin (*Lissodelphis borealis*), common dolphin (*Delphinus delphis*), bottlenose dolphin (*Tursiops truncatus*) and pygmy (*Kogia breviceps*) and dwarf sperm whales (*K. sima*). These sounds that cannot be identified to species were most common in the late summer and through the start of winter, and they are rare in the spring (Figure 17). Generally, whistles, burst-pulses, and echolocation clicks recorded from unknown odontocetes were detected more commonly at night (Figure 18).

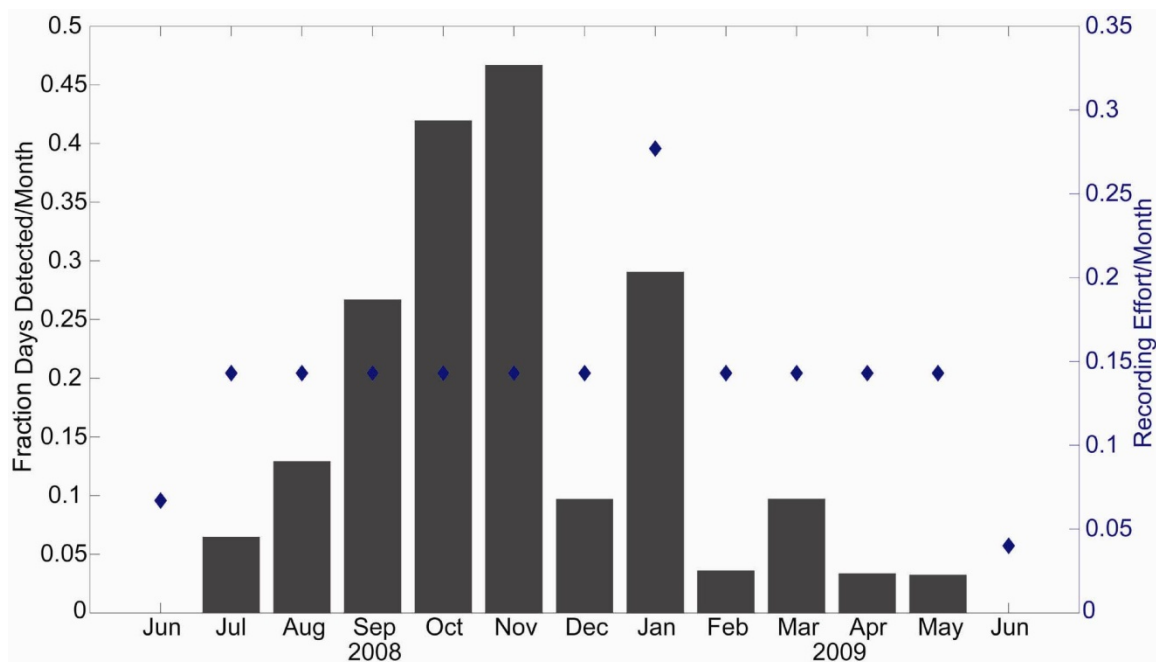


Figure 17. Occurrence of whistles, burst-pulses, and echolocation clicks from unidentified odontocetes between June 2008 and June 2009 recorded at the inshore monitoring site. Black bars represent the fraction of days unidentified odontocete sounds were detected in a month and blue diamonds represent monthly recording effort.

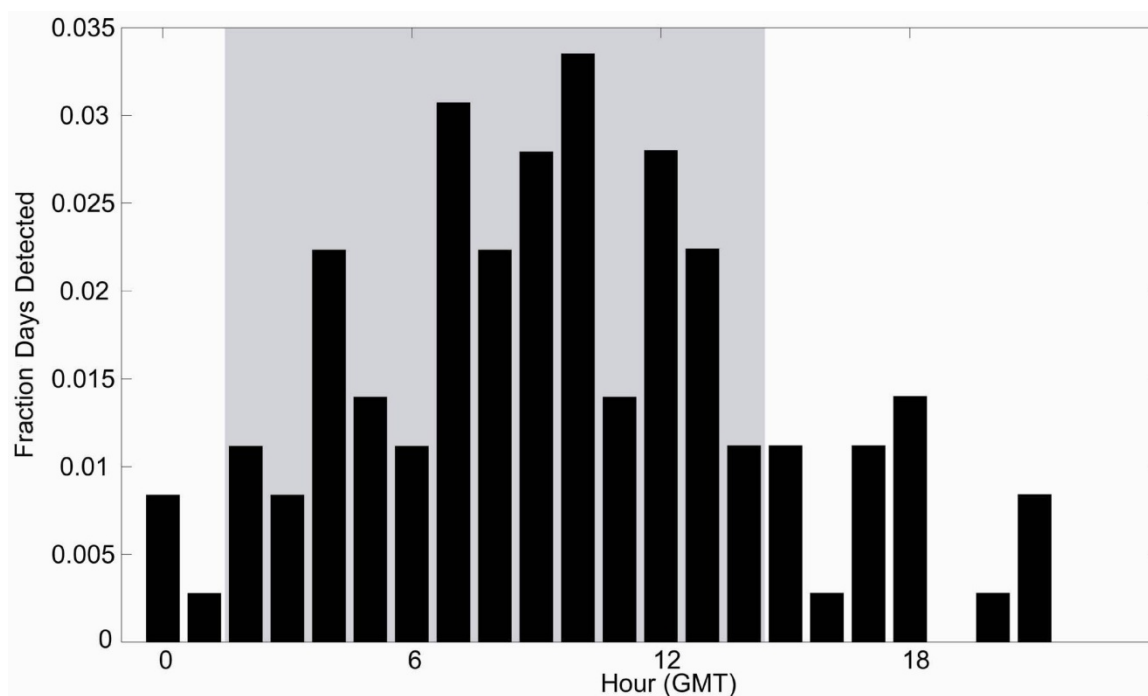


Figure 18. Occurrence of clicks, whistles, and burst-pulse sounds from unidentified odontocetes between June 2008 and June 2009 by hour of the day. Shaded grey area represents average night period at this location through the year.

Porpoises

Harbour (*Phocoena phocoena*) and Dall's porpoise (*Phocoenoides dalli*) were the most frequently sighted marine mammals during visual surveys (Oleson *et al.* 2009, 2010). Both Dall's and harbour porpoises produce clicks that contain energy from 115-149 kHz (Verboom & Kastelein 1995, authors' unpublished data), higher in frequency than the bandwidth of these recordings. Narrow-banded high frequency (NBHF) clicks, with energy from 55-85 kHz and a narrower bandwidth than typical delphinid clicks, were frequently identified in this dataset (Figure 19). There is no known cetacean in the study area which produces echolocation clicks of this description, and these NBHF clicks are most likely a result of spectral aliasing of porpoise clicks (mirroring of energy from above the recording band into the recording band). Given that Dall's porpoises are more frequently sighted in the vicinity of the inshore site, these could be Dall's porpoise clicks. However, since no recordings are available during known presence of either species, this identification should be considered preliminary. As in previous years when these clicks were detected, peak presence of NBHF clicks occurred in the fall (Oleson *et al.* 2009). However, presence of the clicks was relatively constant during the remainder of the year, with only notable decreases in August and January (Figure 20).

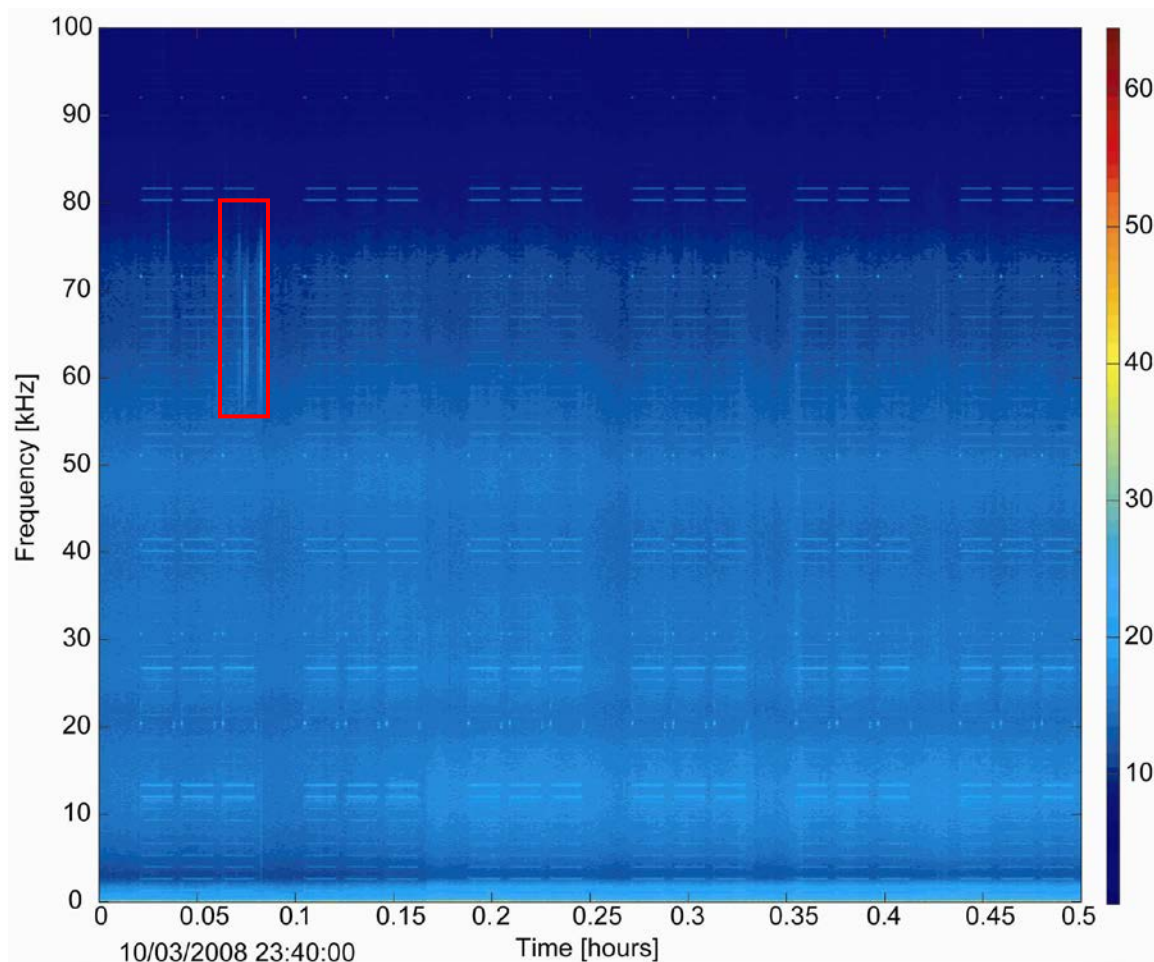


Figure 19. LTSA of high frequency narrow bandwidth pulses (outlined by red box), likely aliased porpoise pulses, recorded at the inshore site in October 2008.

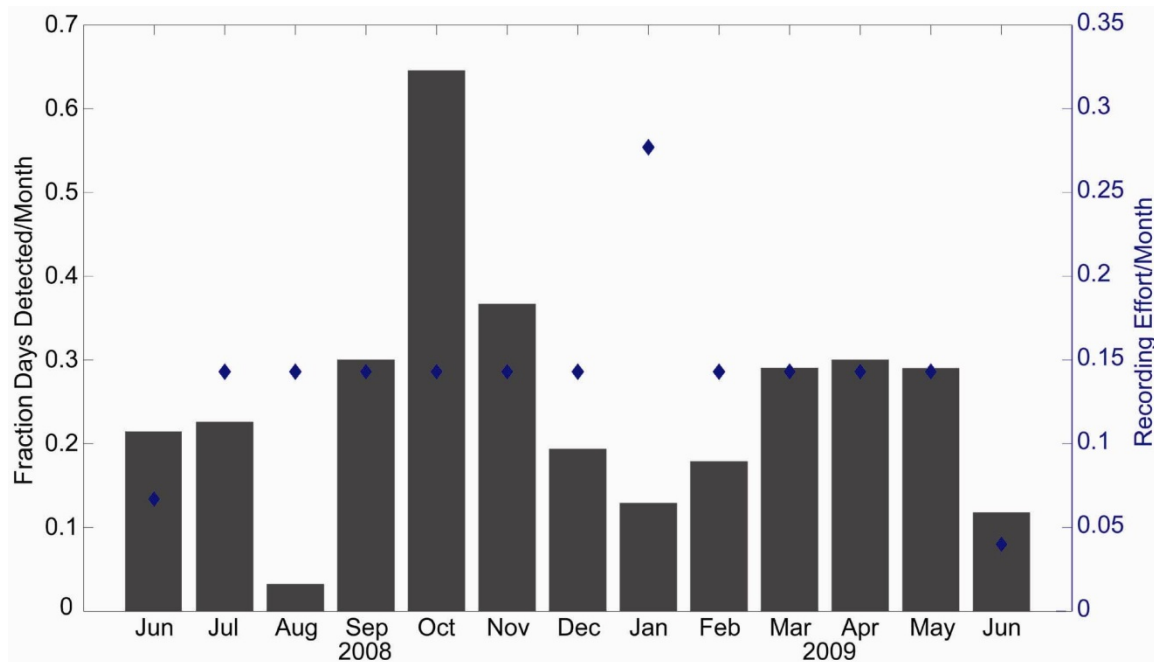


Figure 20. Occurrence of high-frequency narrow-bandwidth (NBHF) clicks, thought to be produced by a porpoise, recorded between June 2008 and June 2009. Black bars represent the fraction of days clicks were detected in a month and blue diamonds represent monthly recording effort.

Pinnipeds

Pinniped sounds were detected only during two days: one in August and one in October 2008. They consisted mainly of barks sounding similar to those heard above water, with most energy between 400 and 600 Hz and of very short durations (< 1 s).

Anthropogenic Noise Sources

Mid-Frequency Active (MFA) Sonar

One occurrence of MFA sonar was recorded on 15 May 2009 (Figure 21). A total of 30 pings were recorded, lasting between 0.5 and 3 seconds with majority of the energy around 3 kHz.

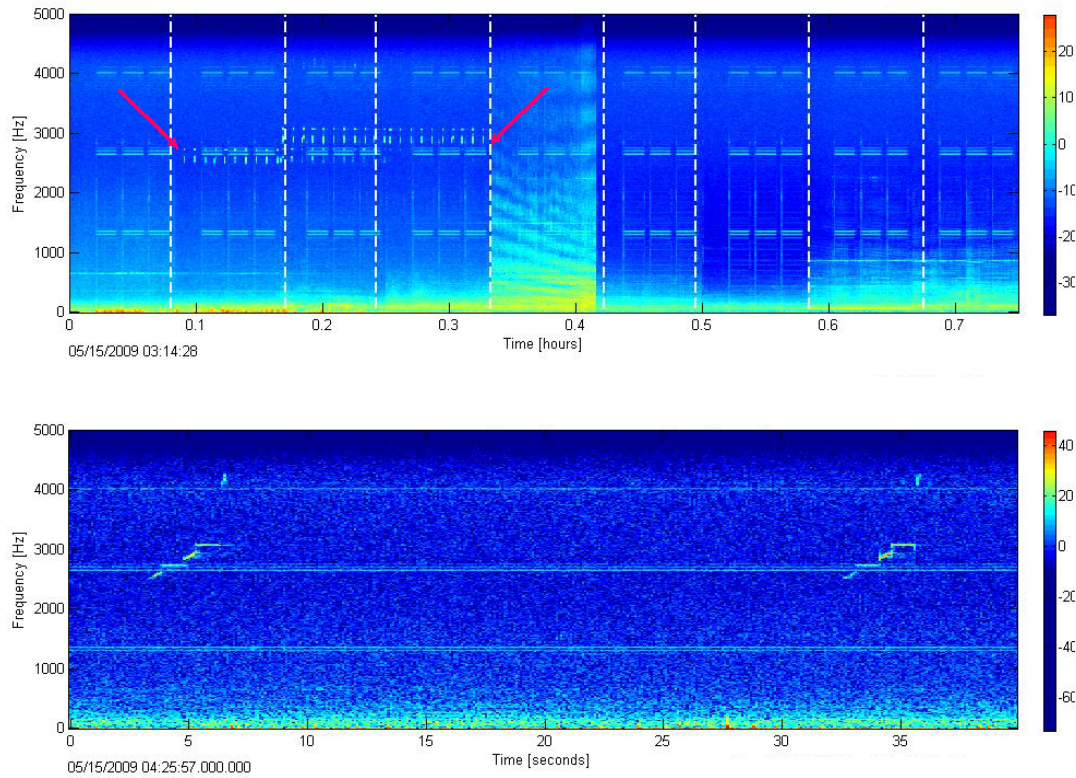


Figure 21. LTSA (**above**) and spectrogram (**below**) of mid-frequency active (MFA) sonar recorded at the inshore site on 15 May 2009.

Explosions

Explosions were logged during the data analysis effort, and, subsequently, they were classified based on their maximum frequency and duration. The duration of each explosion was measured from the time series as the time between the onset of oscillations and the moment when the amplitude of the oscillations was $\frac{1}{2}$ of the maximum amplitude (Figure 22). Based on these measurements, we conclude that logged explosions reported here are probably not from Naval exercises, but are small explosions such as those produced from “seal bombs” used by fishermen. These explosions were more common in the summer and in January (Figure 23), and occur almost entirely during daytime hours (Figure 24).

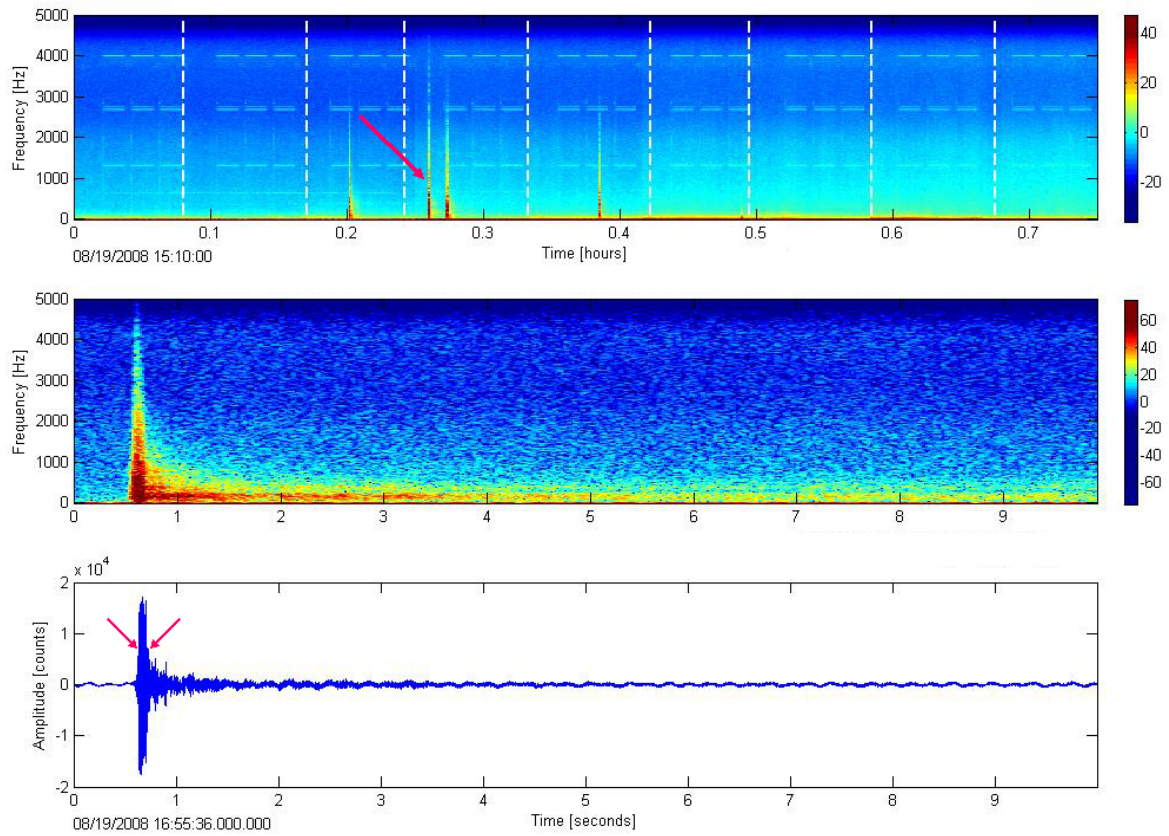


Figure 22. LTSA of several explosions recorded in August 2008 (**above**), with spectrogram (**middle**) and time series (**below**) of one event. Arrows in the time series plot denote times when start and end of the signal was measured, as described in the text.

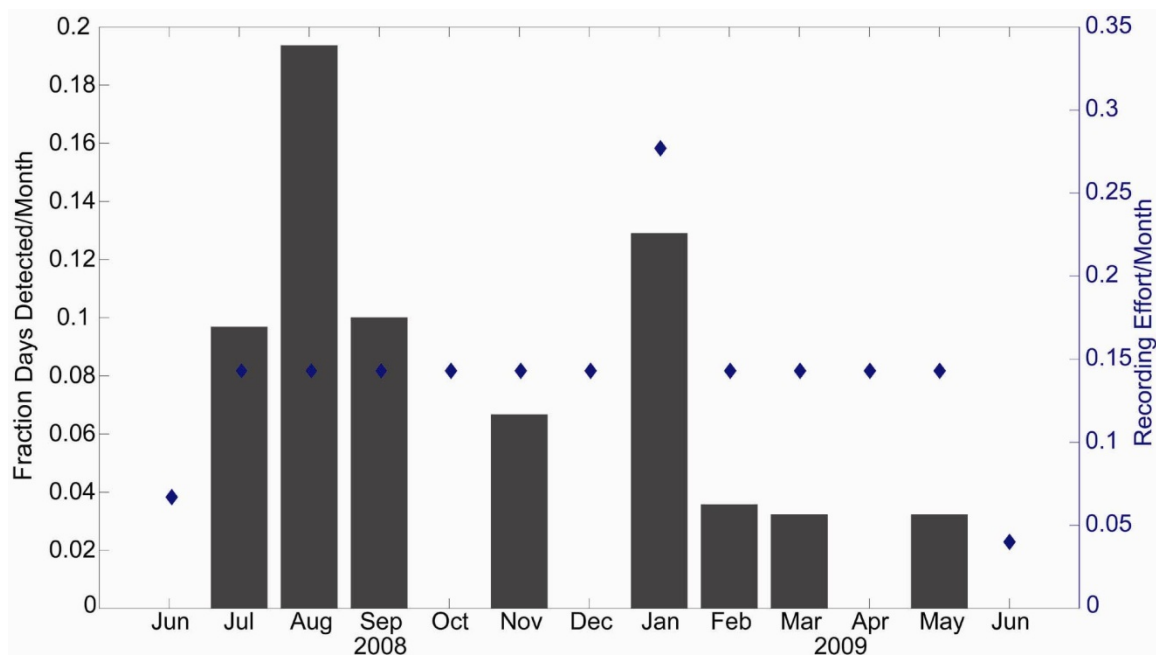


Figure 23. Occurrence of explosions between June 2008 and June 2009. Black bars represent the fraction of days explosions were detected in a month and blue diamonds represent monthly recording effort.

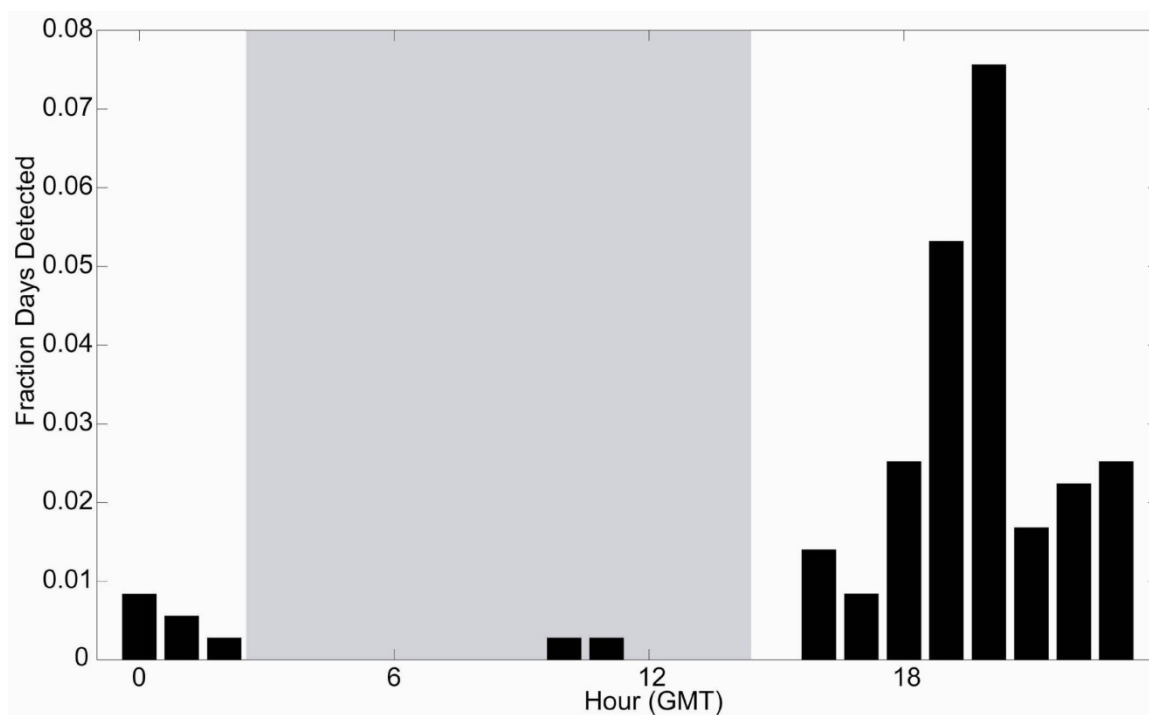


Figure 24. Occurrence of explosions between June 2008 and June 2009 by hour of the day. Shaded grey area represents average night period at this location through the year.

Shipping

When a ship passes relatively close to the HARP, broadband noise can be easily observed and classified as shipping noise. Most broadband ship and boat noise fell within a single duty cycle throughout in this data, indicating ships and boats are generally passing through this area. Shipping noise was common year round, but it decreased in the fall, with a dramatic decline in December 2008 (Figure 25).

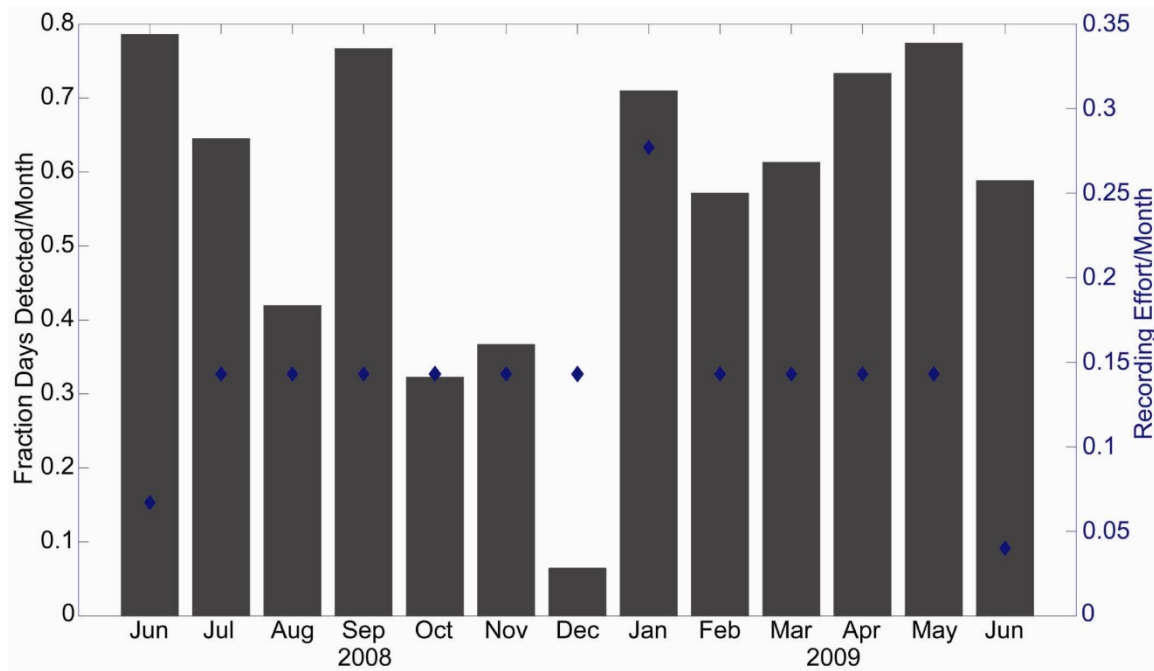


Figure 25. Occurrence of boat and ship noise between June 2008 and June 2009. Black bars represent the fraction of days boats and ships were detected in a month and blue diamonds represent monthly recording effort.

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